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APPLICATION FOR UNITED STATES LETTERS PATENT

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SAW FOR FLEXIBLE SUBSTRATES

BACKGROUND OF THE INVENTION

Wet products such as wet wipes have many applications. They may be used with small children and infants when changing diapers, they may be used for house hold cleaning tasks, they may be used for cleaning hands, they may be used as a bath tissue, they may be used as by a caregiver to clean a disabled or incontinent adult, or they may be used in and for a whole host of other applications, where it is advantages to have a wipe or towel that has some moisture in it.

Wet wipes have been traditionally been made in processes in which larger webs of wipes are initially made and than these larger webs are converted into smaller rolls or sheets that can be placed in a dispenser. Examples of such dispensers are disclosed in pending U.S. application entitled System and Dispenser for Dispensing Wet Wipes, Serial No. 09/565,227 filed May 4, 2000; pending U.S. application entitled Wipes Dispensing System, Serial No. 09/659,295, filed September 12, 2000; and pending U.S. application entitled Mounting System for a Wet Wipes Dispenser, Serial No. 09/659,307, filed September 12, 2000, the disclosures of which are incorporated herein by reference.

Wet wipes can be any wipe, towel tissue or sheet like product including natural fibers, synthetic fibers, synthetic material and combinations thereof, that is wet or moist. Examples of wet wipes are disclosed in application serial numbers 09/564,449; 09/564,213; 09/565,125; 09/564,837; 09/564,939; 09/564,531; 09/564,268; 09/564,424; 09/564,780; 09/564,212; 09/565,623 all filed May 4, 2000, and application serial no. 09/223,999 entitled Ion-Sensitive Hard Water Dispersible Polymers And Applications Therefore, filed December 31, 1998 the disclosures of which are incorporated herein by reference.

BRIEF SUMMARY OF THE INVENTION

In an embodiment of the invention there is provided a method of cutting a flexible log comprising: depositing a log of substrate in a pocket; the pocket comprising an open end and a closed end; the pocket comprising a first planar surface, a second planar surface, and a concave surface between the planar surfaces; wherein the second planar surface is larger than the first planar surface, and wherein the concave surface forms the closed end; dividing the log into a plurality of rolls with a cutting force; and holding the rolls in the pocket such that the cutting force is counterbalanced by the pocket.

These embodiments may further comprise the dividing comprising contacting the log with a plurality of cutting devices; cutting devices which are circular saw blades; and the pocket further comprising channels through which the cutting devices can pass. These embodiments may further comprise the holding comprising removing the cutting devices from the substrate once the log has been divided into rolls; the pocket further comprising a width defined by the distance between the first and second planar surfaces; wherein the width is greater than the diameter of the log; holding comprising containing the log within the pocket without covering the open end; and holding comprising counterbalancing the cutting force with a reaction force from the first planar surface and the concave surface.

These embodiments may further comprise a first planar surface having a width less than about 25 mm and a length between 50 mm and 360 mm; a second planar surface having a width less than about 155 mm and a length between 50 mm and 360 mm; a concave surface having a radius of curvature between 12 mm and 130 mm; a distance between the planar surfaces between 50 mm and 250 mm; and a pocket mounted with a plurality of other pockets on a rotating sprocket, the rotating sprocket having a horizontal axis. The depositing may occur when the pocket is at an angle between 30-degrees and 80-degrees from the horizontal axis; the depositing may occur when the pocket is at an angle of 45-degrees from the horizontal axis; the deposited log may be supported by the second planar surface and the concave surface; the deposited log may be rotated to a cutting area; the log in

the cutting area may be between 60-degrees and 110-degrees from the horizontal axis or between 75-degrees and 90-degrees from the horizontal axis; the dividing may comprise pivoting a plurality of saw blades into the log; the cutting force may comprise an impact force of the blades on the substrate and a friction force between the blades and the substrate; the holding may comprise counterbalancing the cutting force with a reaction force from the first planar surface and the concave surface; the holding may comprise removing the saw blades from the pocket once the log has been divided into rolls; and the removing may be complete when the log is between 65-degrees and 115-degrees from the horizontal axis or, when the log is between 80-degrees and 110-degrees from the horizontal axis, or when the log is between 85-degrees and 90-degrees from the horizontal axis. These embodiments may further comprise rotating the rolls to a collection apparatus; and the roll may be prevented from dropping out of the pocket by a roll retention device; the roll retention device may be a retention shoe; and the collection apparatus may comprise a diverter.

In a further embodiment of the present invention there is provided an apparatus for cutting a flexible log comprising: a cutting device; a pocket, the pocket comprising an open end, a closed end, a first planar surface, a second planar surface, wherein the second planar surface is larger than the first planar surface, and a concave surface between the planar surfaces, wherein the concave surface forms the closed end; a plurality of channels, the channels situated in the pocket; and a sprocket, the sprocket supporting the pocket, the sprocket rotating about an axis.

These embodiments may further comprise a distance between the first and second planar surfaces greater than the diameter of the log. The cutting device may exert a force on the log; the pocket may counterbalance the forces exerted on the log by the cutting device; the first planar surface and the concave surface may counterbalance the forces exerted on the log by the cutting device; the cutting device may be configured to pass through the channels; the cutting device may comprise circular saw blades; the first planar surface may have a width less than about 25 mm and a length between 50

mm and 360 mm; the second planar surface may have a width less than about 155 mm and a length between 50 mm and 360 mm; the concave surface may have a radius of curvature between 12 mm and 130 mm; the distance between the planar surfaces may be between 50 mm and 250 mm; and the sprocket may support a plurality of pockets.

In a further embodiment of the present invention there is provided a method of cutting a flexible log comprising: depositing a log of substrate in a pocket having an open end; the pocket comprising a first planar surface, a second planar surface, and a concave surface between the planar surfaces; wherein the second planar surface is larger than the first planar surface; the pocket comprising channels; the pocket mounted with a plurality of other pockets on a rotating sprocket; rotating the deposited log to a cutting area; moving a plurality of saw blades into the log, the blades passing through the channels; dividing the log into a plurality of rolls with a cutting force; counterbalancing the cutting force with a reaction force from the first planar surface and the concave surface; and removing the saw blades from the pocket once the log has been divided into rolls.

In a further embodiment of the present invention there is provided a pocket for holding flexible logs comprising: a base, the base defining a horizontal axis; an open end; a closed end; a first planar surface, the first planar surface having a width less than about 25 mm and a length between 50 mm and 360 mm; a second planar surface, the second planar surface having a width less than about 155 mm and a length between 50 mm and 360 mm; and a curved surface, the curved surface having a radius of curvature between 12 mm and 130 mm; wherein the planar surfaces are at an angle of 60-degrees above the horizontal axis, and wherein the planar surfaces are separated by a distance between 50 mm and 250 mm.

In a further embodiment of the present invention there is provided a method of cutting a flexible log comprising: a) rotating a pocket to a delivery position; the pocket mounted on a sprocket having a first horizontal axis; the pocket comprising a first wall, a second wall, and a bottom; the pocket in the delivery position at an angle between 30-degrees and 80-degrees from the

first horizontal axis; b) delivering a log to the pocket at the delivery position, wherein the log is supported by the first wall and the bottom; c) rotating the pocket and log to a cutting area, the pocket in the cutting area at an angle between 60-degrees and 110-degrees from the first horizontal axis; d) moving a saw downward to a lowered position to contact the log; the saw comprising a plurality of circular blades; the saw mounted on an arm having a second horizontal axis; the arm moving the saw to the lowered position by pivoting between 5-degrees and 15-degrees below the second horizontal axis; e) applying a cutting force to the log with the saw such that the log is completely divided; f) holding the log in the pocket by counterbalancing the cutting force with a reaction force from the second wall and the bottom; g) moving the saw upward to a raised position when the log is between 80-degrees and 110-degrees from the first horizontal axis, the arm moving the saw to the raised position by pivoting between 5-degrees and 30-degrees above the second horizontal axis; and h) rotating the pocket and the log away from the cutting area.

In a further embodiment of the present invention there is provided method of cutting an elongate substrate comprising: providing the elongate substrate in a plurality of pockets, the pockets being positioned to support the substrate along its length; dividing the substrate into a plurality of rolls with a plurality of circular saw blades; exerting an upward vertical force on the rolls while the saw blades are in contact with the rolls; and counterbalancing the upward vertical force to maintain the rolls in the pockets without the use of an external structure to hold the rolls in the pockets.

In a further embodiment of the present invention there is provided an apparatus for cutting an elongate substrate comprising: a plurality of pockets, the pockets being positioned to support the substrate along its length; a plurality of circular saw blades, the saw blades cutting the substrate into a plurality of rolls and exerting an upward vertical force on the rolls while the saw blades are in contact with the rolls; and the pockets being configured to maintain the rolls in the pockets without the use of an external structure to hold the rolls in the pockets.

In a further embodiment of the present invention there is provided a method of cutting a flexible log comprising: providing a cutting device, the cutting device comprising a plurality of saw blades and at least one support arm; depositing a log of substrate in a pocket; the pocket having a plurality of channels, and the pocket mounted on a rotating sprocket; simultaneously rotating the sprocket and pivoting the support arm such that the cutting device and the pocket containing the log converge in a cutting area; dividing the log into a plurality of rolls by passing the saw blades through the channels; and simultaneously rotating the sprocket and pivoting the support arm such that the cutting device and the pocket containing the log are separated.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

Figure 1 is a side view of an apparatus.

Figure 2 is a detail side view of the apparatus of Figure 1.

Figure 3 is a partial perspective view of an apparatus.

Figure 4 is a view of a pocket.

Figure 5 is a side view of an apparatus.

Figure 6 is a side view of an apparatus.

Figure 7 is a side view of an apparatus.

Figure 8 is a side view of a conveyor.

Figure 9 is a side cross-sectional view of a conveyor.

Figure 10 is a frame view of a conveyor.

Figure 11 is a diagram of the forces applied to a log.

Figure 12 is an operator side view of a sprocket.

Figure 13 is a drive side view of a sprocket.

Figure 14 is a front partial section view of a sprocket.

Figure 15 is a side view of a cutting assembly.

Figure 16 is a front view of a cutting assembly.

Figure 17 is a front view of one set of blades.

Figures 18-19 are side views of a blade.

Figures 20-21 are views of a bearing block.

Figures 22-25 are views of blade couplings.

Figure 26 is a side view of a honing assembly.

Figure 27 is a front view of a frame for a honing assembly.

Figure 28 is a section view of a frame for a honing assembly.

Figure 29 is a back view of a section of a honing assembly.

Figure 30 is a top view of a honing assembly.

Figure 31 is a side view of a set of hones.

Figure 32 is a front view of a set of hones.

Figure 33 is a top view of a diverter.

Figure 34 is an end view of a diverter.

Figure 35 is a side view of a diverter.

Figures 36-38 are schematic views of a saw and a sprocket.

Figures 39-40 are side views of a sprocket, diverter, and index conveyors.

DETAILED DESCRIPTION OF THE INVENTION

An apparatus for cutting a substrate into individual rolls is provided which in general provides for cutting low rigidity substrate logs, such as moistened logs, into rolls. The use of this apparatus minimizes distortion of the finished product, especially in terms of shape and cut squareness. This apparatus can be used to process moistened product, and it provides a sanitary processing environment due to its reduced potential for microbial growth.

As shown in Figure 1, there is provided in general an apparatus 1 that cuts an entire log 20 of substrate into individual rolls 22. Logs are delivered into a distribution sprocket 10 and are transported in a direction perpendicular to the longitudinal axis of the log. The pockets 14 in the distribution sprocket are shaped to hold logs during the cutting operation without the need to use a secondary clamping device. A log which is nested into the sprocket is supported along its entire length and rotated into a cutting area 80 (Figure 2) where it is divided into rolls by a cutting device, such as a multi-blade rotary saw 8 having a common axis 54. The divided log is rotated past the cutting area, and the individual rolls are secured in the pockets by a roll retention

device 24. The retention device prevents the rolls from leaving the pockets until the desired roll exit point 56 is reached. Unwinding and scuffing of the rolls is also prevented by the retention device. The rolls may be deposited on a diverter 34 which then delivers the rolls to an index conveyor 33 for further processing.

Substrates for which this apparatus is useful are any type of substantially cylindrical rolls or logs. For example, the substrate could be a solid cylinder of material, a hollow cylinder such as a pipe or tube, or a wound roll of a web. The apparatus is particularly useful for wound rolls having low rigidity, for example moistened logs such as would be used as precursors for rolls of wet wipes. The low rigidity substrate may be other soft or flexible logs such as foams, sponge-like materials, food products, etc. For example, the substrate may be a log of a cheese product or meat product. Also, the substrate may be a dry roll of paper, such as tissue paper. Since the substrate is secured during the cutting procedure, there is no need for a spindle or mandrel to be used for roll products. Thus, coreless rolls of wet wipes can be cut precisely by this apparatus.

Examples of wet wipes rolls which may be produced by this apparatus include those described in the patent applications listed above. A log of wet wipes from which such rolls are cut may have a diameter between 50 mm and 140 mm, preferably between 75 mm and 120 mm, and more preferably about 73 mm. When unwound into a sheet, the length of the resulting sheet may be between 400 inches (10 m) to 1000 inches (25 m), preferably about 450 inches (11.5 m). The wound log has a length along its longitudinal axis between about 2540 mm to 3050 mm, preferably 2620 mm to 2920 mm, more preferably about 2690 mm. The wet wipes have a moisture content above 50 percent-by-weight (wt%), preferably above 65 wt%, more preferably about 69 wt%.

Referring to Figure 1, the logs may be delivered initially to an infeed conveyor 12. The delivery may be metered if necessary, such as by a controllably movable gate 26. The conveyor is mounted on a frame 6. The conveyor is preferably made of 316L stainless steel. The conveyor may be

movably mounted such that it can be in a lowered position 72 during use or can be in a raised position 74 for maintenance or cleaning. The conveyor may be mounted to the frame by support arms 73, which are connected to struts 69 and servo motors 71 (Figures 9-10). These support arms raise or lower the conveyor in response to a signal from an actuator.

The infeed conveyor is equipped with concave holders 18 which cradle the logs and prevent them from falling off the conveyor. The holders are preferably shaped as shown in Figures 1 or 6 with planar walls and a curved bottom. This configuration allows the roll to be dropped into the holder in a vertical manner, rather than rolling in at an angle. The optional metering gate 26 can also assist in assuring this vertical delivery. Holders of different dimensions and configurations may be employed for different substrates. For example, holder 58 (Figure 5) may have a curved bottom and a supporting wall. The holder may be a shelf 59 which is substantially perpendicular to the direction of motion of the conveyor, as shown in Figure 7. The conveyor may be equipped to support a variety of interchangeable holders.

The logs may be delivered to the infeed conveyor in a consistent manner, such that the logs are in alignment with each other. It is preferred that the logs are also substantially aligned with respect to the log saw apparatus. Portions of the log that extend beyond the outermost saw blades may produce rolls which have dimensions and/or edges that are undesirable. If an end of the log does not extend to the outermost blade, the roll from that end may also have dimensions and/or edges that are undesirable. These rolls with non-optimal or inconsistent dimensions may then be treated as waste or may be recycled or put to other uses. It is preferred that a relatively small portion of the substrate log is cut from each end of the log by the outermost saw blades such that the inconsistent rolls account for less than 10%, preferably less than 5%, and preferably between about 1% and 3% of the total length of the log. Any logs that are out of alignment may be aligned manually as needed, although an automated alignment system could also be employed.

Moving in the direction of arrow 60, the infeed conveyor delivers the log to the distribution sprocket 10 by allowing the log to fall out of the holder onto a guide plate 28. The holders on the conveyor are supported by wear strips, which are preferably made of ultra-high molecular weight (UHMW) polyethylene. The rotation of the roll on the guide plate is in the direction of arrow 62 as illustrated in Figure 2. This rotation is preferably such that, at the point of contact between the tail of the roll and the surface, the motion of the tail is opposite the overall motion of the roll itself. This inhibits any unwinding of the roll. This guide plate may be equipped with a controllably movable gate 30 (Figure 1) to meter the delivery to the sprocket. Optionally, the infeed conveyor may allow the roll to fall directly into the pocket 14 in the distribution sprocket.

The distribution sprocket 10 rotates the log in the direction of arrow 64 into the cutting area 80. The rotation of the sprocket is preferably a continuous motion, although intermittent or stepwise movement may be employed. The sprocket rotates the divided roll away from the cutting area such that the individual rolls may be collected. The rolls may be dropped onto a diverter 34 (Figure 1), into a receptacle or bin 36 (Figure 5), or onto a conveyor 31 (Figure 7). The rolls may also be ejected from the sprocket. The rolls may then be delivered for subsequent processing and/or packaging or may be tested to monitor product quality. The sprocket is mounted on a frame 4 and rotates on a rotating shaft 82 attached to servo motor 84 (Figure 14).

The sprocket has pockets 14 for delivering the log to the cutting area. In the embodiment shown in Figure 4, the pocket has a base 79, planar portions 76 and 78, and a curved portion 77. The curved portion forms a closed end of the pocket, with an open end formed by the space between the planar portions. The planar walls 76 and 78 of the pocket are at an angle of 60-degrees from the horizontal axis 140, which is defined by the base of the pocket. The configuration in this embodiment provides for ease of delivery of the log into the pocket from the infeed conveyor 12 and also provides stability to the log during the cutting procedure. As shown in Figures 36 and 38, the

log is preferably delivered to the sprocket when the receiving pocket is at an angle of 45-degrees from the horizontal axis 123. Other angles of delivery can be used, depending on the overall configuration of the apparatus. The log may be delivered when the receiving pocket is between 30-degrees and 80-degrees from the horizontal axis 123.

Pockets of different dimensions and configurations, as illustrated for example in Figure 5, may be employed for different substrates or final products. The sprocket may be equipped to support a variety of interchangeable pockets. By way of example, a pocket 14 for use with a roll having a diameter of 73 mm has preferred dimensions. Curved portion 77 has a radius of curvature 142 of 1.50 inches (38.1 mm), and the radius has a center 144. Planar wall 76 has a width 145 of 2.06 inches (52.3 mm) and has a curved lip 146 at the open end with a radius of curvature of 0.50 inch (12.7 mm). Planar wall 78 has a width 147 of 0.38 inch (9.7 mm) and has a curved lip 148 at the open end with a radius of curvature of 0.25 inch (6.4 mm). The distance 150 between the planar portions is 3.00 inches (76.2 mm). Pockets 14 for use with logs that are larger or smaller than this can have different dimensions. For example, the radius of curvature 142 may be between 12 mm and 130 mm; wall 76 may have a width 145 less than 150 mm; wall 78 may have a width 147 less than 25 mm; and distance 150 may be between 50 mm and 250 mm.

The pocket has a multiplicity of channels 32 (Figures 3-4), which are configured so as to allow the blades to pass through them. The spacing of these channels along the length of the sprocket helps define the width of the roll that is produced. The spacing is equal to the length of the walls 76 and 78 and the curve portion 77 and may be between 50 mm and 360 mm. For rolls of wet wipes, the length may be about 95 mm.

It is preferred that the channels are narrow enough to provide sufficient support for the substrate, yet wide enough to allow the blade to pass through and to allow for thorough cleaning of the sprocket. For example, if the thickness of the blade is 0.157 inch (4.0 mm), the width of each channel may be 3/8 inch (9.5 mm). The channels may have other dimensions. A single log

may be supported by a singular pocket 14 which contains channels 32 as grooves in the pocket. Alternatively, a single log or roll may be supported by a plurality of pockets in a linear arrangement. In this embodiment, the lateral spacing of these pockets from each other serves to form the channels, and the pockets in the linear arrangement form a pocket assembly. The sprocket itself may have grooves which contribute to the channel, and such a sprocket can be used with singular pockets or with pocket assemblies. The sprocket is preferably made of 316L stainless steel, and the pockets are preferably made of 907 cast nylon. Preferably, the sprocket comprises 8 singular pockets, equally spaced 45-degrees from each other. The distance from the centers of the radius of curvature 144 of two pockets separated by 180-degrees is preferably about 840 mm.

Any type of cutting device or saw may be used to cut the roll or log. For example, a band saw or knife blades may be used. A water jet cutting apparatus, such as is available from FLOW INTERNATIONAL, Seattle, WA, may be used. Circular saw blades are presently preferred, and a diameter of 20-24 inches (508-610 mm) provides for complete cutting of a log having a diameter of 73 mm while ensuring clearance of the blade shaft. Blades useful in this embodiment include those available from ORBITAL SAW CO, INC. The model 412034 is a nickel plated blade made of D-2 high-chrome tool steel, with a 24 inch (610 mm) diameter, 3.25 inch (82.6 mm) inner diameter (ID) bore, and a 0.150 inch (3.81 mm) thickness. Cutting devices of different sizes and/or configurations may be employed for different substrates.

In an embodiment of the invention, the saw 8 comprises a plurality of circular blades 16 and is mounted on a frame 2. The number of blades depends on the number of individual rolls 22 desired and is greater than the number of rolls. These blades can be mounted separately, or can be mounted on one common shaft, or can be mounted in discrete sections on more than one common shaft. The blades can be operated independently, or can be operated in at least one group. The blades can be mounted on at least one common shaft 54 and can be operated by one common motor. In an embodiment of the invention, half the blades are mounted on one common

shaft 42, and half the blades are on another common shaft 44. These shafts can be operated by one common motor or can be connected to separate motors 85 and 86.

In the embodiments shown in Figures 15-25, 26 total blades, 13 each on shafts 42 and 44, form two cutting assemblies. These two assemblies together can produce 25 rolls of the desired dimensions from one log. For an individual assembly (Figure 17), a shaft is mounted on a pair of pivoting support arms 88 and 90. All of the blades but one are mounted between these arms, with the remaining blade mounted on the interior end 94 of the assembly, the motor being connected to the exterior end 92 of the assembly. The support arms are pivotably mounted to the frame 2 by a pivot shaft 99. The distance between the centers of the blade shaft and the pivot shaft is 24 inches (0.6 m). The spacing between the blades is 4.125 inches (10.5 cm).

The shaft rotates inside a bearing mounting 95 on each support arm. The bearing mounting 95 has a housing 91 which is removably attached to a support arm, and the blade shaft moves over the bearings 93. The blades are removably mounted to the shaft by couplings 96 (Figures 22-23), or by coupling 98 for the blade at the interior end (Figures 24-25). The blades can be removed from the couplings by loosening the screws 97 on the coupling. This allows the blades to be serviced, inspected, or replaced. The blades on the shaft can be accessed by separating the bearing mounting on the interior end from the support arm 90, the shaft being secured by support arm 88. The blades are removed from the couplings and then removed from the shaft. The new blades are then installed into the couplings. Alternatively, the blade and the coupling together can be removed from the shaft before the blade is replaced. The coupling can then be fitted with a new blade, and the blade and coupling together can be mounted onto the shaft. Once the blade replacement is complete, the bearing housing can be re-secured to the support arm.

The spacing 46 of the blades relative to each other determines the size of the individual rolls produced. It follows that the consistency of this spacing affects the consistency of the product. Also, the spacing and configuration of

the blades relative to the dimensions of the log affects the amount of waste produced by cutting the log. If the log is longer than the end-to-end distance of the array of blades, one or both ends may produce rolls which are too small to be of commercial value. The ends, or cookies, are waste material and are generally disposed of. It is desirable to reduce the size of these cookies, or to eliminate them if possible, so as to reduce the overall waste of the production. To the extent that the cookies are not eliminated, it may be necessary to remove them from the apparatus such as by way of a chute 70 (Figure 5). This chute may deliver the cookies directly to a container for discarding or recycling, or the chute may deliver the cookies to a conveyor which removes them from the apparatus. For the wet wipes logs described above, the cookies preferably have a width of 1.5 inches (38 mm) or smaller.

The blades can divide the log in a variety of ways. The saw 8 can remain in the down position 38 such that the blades are in the cutting area 80, and the log can be rotated into the blade. Also, the log can be held stationary for a period of time, and the saw can be moved through the log. Figures 36-38 illustrate an embodiment in which the blades oscillate between a raised position 120 and a lowered position 122. In the raised position 120, the support arm is about 10-degrees above the horizontal axis 126. In the lowered position 122, the support arm is about 7-degrees below the horizontal. This lowered position corresponds to having the blades in the cutting area. In this embodiment, the sprocket moves in a continuous manner. The blades are lowered and contact the log when the log is between 5 and 10-degrees from the vertical axis 128. The raised and lowered positions may have different angles of displacement. For example, the raised position 120 may be between 5-degrees and 30-degrees above the horizontal axis 126; and the lowered position 122 may be between 5-degrees and 15-degrees below the horizontal axis 126.

Although it is possible that two logs could be in contact with the blades at one time, it is preferred that the blade is in contact with only one log during a cutting cycle. Once the log has been completely divided, the saw 8 is raised out of the cutting area. Depending on the speed of the sprocket, the log can

have different positions at the time the blades are removed from the cutting area. It is preferred that the cutting is complete and the blades are removed by the time the log is centered on the vertical axis. It is preferred that the blades operate at a variable speed between 1500 rpm and 1700 rpm. The use of variable speeds is known to those in the art as a method to minimize vibrations in the apparatus.

Preferably the saw blades 16 rotate in the direction opposite that of the sprocket as shown in Figure 2. Figure 11 shows a diagram of the forces exerted on a log during the cutting process, along with an illustration of the vector sum of those forces. The forces are represented as arrows or vectors having both a direction, which indicates the overall direction of the force, as well as a length, which indicates the relative magnitude of the force. The force F_{Tot} is the total force due to the blade, and is the sum of the forces due to the blade impacting the log F_{Imp} and due to the friction between the blades and the log and/or divided rolls F_{Bld}. This can be expressed mathematically as

$$F_{Tot} = F_{Imp} + F_{Bld}.$$

The force W is the force of gravity on the log, thus the vector points down. The force F_{Cen} is the centrifugal force due to the angular momentum of the log. The force F_{Pct} is the reaction force exerted by the pocket against these forces. For the log or roll to remain in the pocket, the net force on the substrate must be zero. This is expressed mathematically as

$$F_{Tot} + F_{Cen} + F_{Pct} + W = 0.$$

This relation can be illustrated by the head-to-tail arrangement of the vectors in Figure 11. Since the vectors form a complete cycle, there is no net vector that can be drawn from a tail to a head. Any vector that could be drawn would indicate a net force, and this force would result in motion of the log.

The shape of the pocket as shown in Figures 4, 11 and 36-38 helps to maintain a zero net force on the substrate by providing an effective reaction force, especially against F_{Tot}. The force F_{Tot} of the blade in the direction of arrow 66 pushes the substrate into the shorter of the two planar walls 78 of the pocket, and this wall exerts an equal and opposite reaction force. Without

this wall, the substrate could be forced out of the pocket by F_{Tot}. The removal of the saw blades after the cut eliminates F_{Tot}. The pocket reaction force F_{Pct} thus only acts to counterbalance the force of gravity and any centrifugal force. Since F_{Bld} is dependent on a wide variety of factors, including surface characteristics of the blade, lubricating additives, substrate composition, and relative speeds of operation, it is possible to reduce F_{Bld}, and thus F_{Tot}, such that removal of the blades from the cutting area is not necessary. It is presently preferred that the blades are removed from the cutting area before the substrate is centered on the vertical axis.

The shape of the pocket and the action of the saw blades eliminate the need to clamp the roll to the sprocket. Deformation of the substrate can occur if clamps, skates, or other devices are used to substantially close the opening of the pocket during the cutting procedure. Use of these devices also provides increased difficulties in the maintenance and cleaning of the apparatus as a whole. The shape of the pocket also provides for support of the divided roll after the cutting procedure. The angled configuration prevents the roll from rotating out of the pocket until the substrate is centered at an angle of about 10-degrees below the vertical axis 128. Thus, the shape of the pocket provides for the substrate to be dropped into the pocket, secured through the cutting procedure, supported after cutting, and delivered to an exit point.

After the log is cut into individual rolls, the individual rolls are dispensed from the sprocket. This dispensing can take the form of allowing the roll to fall from the pocket. The sprocket and/or pocket can be equipped with a movable finger 48 (Figure 2) to eject the rolls from the pocket, for example in a substantially horizontal motion. If the rolls are allowed to fall from the pocket, it may be desirable to prevent this dispensing until the roll has been rotated to an exit point 56. This can be accomplished by methods known to those skilled in the art. For example, a belt 50 or series of belts can be used (Figures 5 and 7) to cover the openings of the pockets until the exit point is reached. In the embodiment shown in Figure 1, a shoe or plate 24 may be used. The dimensions of the belt or shoe necessary to control the dispensing

can vary by the type of substrate and the shape of the pockets. The belt or shoe may be connected to the frame by a mounting bracket 25. In any of these embodiments, an exit dead plate 52 (Figure 5) may also be employed to guide the dispensed roll to the desired location. A pivoting exit plate 53 (Figure 7) may be used to direct the rolls to two or more different locations.

A diverter 34 may be employed to facilitate the transport of rolls away from the apparatus from a single exit point, or discharge location. Examples of diverters are illustrated in Figures 1, 6, 33-35, and 39-40. The diverter is located between the sprocket 10 and the index conveyors 33 and moves in the direction of arrow 125. The diverter comprises two receivers 130 and 131, each receiver having a pair of concave doors 134. The curved shape of the receivers assists in minimizing distortion of the rolls of product. The diverter is mounted on a frame 35 and is moved by a drive pulley 137 and an idler pulley 138. The receivers and the frame are made of 316L stainless steel, the drive pulley is made of AISI 4150 steel (electroless nickel coated), and the idler pulley is made of poly(ethylene terephthalate) (PET), specifically Ertalyte PET-P.

One receiver can hold an entire group of rolls formed from a single log. The diverter slides horizontally to a delivery position above one of the index conveyors and then opens its doors to deposit the rolls onto the conveyor. The conveyor can be in motion or can be stationary. It is presently preferred that the conveyor is stationary as the rolls are deposited and then moves the rolls a predetermined distance. The doors on the receiver are hingedly attached to the sides 136 of the receiver. The doors meet near the center, thus acting as “bombay” doors. The doors are operated with ALLEN BRADLEY servo motors and THOMSON MICRON gearboxes.

The index conveyors 33 travel in a direction perpendicular to arrow 125. The index conveyors may travel in other directions, but it is preferred that the portion of the index conveyor that is directly beneath the diverter is parallel to the receivers. The conveyors may be any kind of belt made of a corrosion resistant metal, plastic, or cloth. It is preferred that the conveyor belts are made of polyurethane that is molded to have a curved center as

illustrated in Figures 39 and 40. This curved center helps to cradle the rolls that are dropped from the receiver so as to inhibit the rolls from bouncing and to keep them on the conveyor when they are indexed away from the machine. The index conveyors are mounted on a frame 37 of 316L stainless steel. The motion of the conveyor may be continuous or may be an indexing motion. It is presently preferred that a given index conveyor is stationary when the rolls are dropped onto it. The conveyor is then moved a specific distance to index the rolls away from the apparatus and to provide an empty section of the conveyor for the next group of rolls.

The spacing between receivers on the diverter is preferably the same as the spacing between the index conveyors. This configuration allows the one receiver to be loaded with rolls at the same time that the other receiver is depositing rolls onto an index conveyor. This simultaneous action provides for a lower acceptable sliding speed than would be required if a single receiver processed each set of rolls. The speed of the sliding action of the diverter is dependent on factors including the speed of the log saw apparatus and the number of indexing conveyors. For an apparatus dividing one log every 1.8 seconds and employing two index conveyors, it is preferred that the diverter slide at a rate of 41.25 inches (1048 mm) per second. The action of the diverter, that is the timing of the loading, unloading, and sliding, can be adjusted to accommodate the conveyor configuration. Tables 1-4 provide examples of the steps carried out by the diverter for four different scenarios using three different index conveyors. Figure 39 illustrates the diverter and index conveyors with the diverter in position A. Figure 40 illustrates the diverter and index conveyors with the diverter in position B. The conveyors are labeled C1, C2, and C3 from left to right.

Table 1

Conveyors C1 and C2 Operating	
TASK	TIME (s)
Diverter in position A	
Load rolls into receiver 130	0.25
Cycle diverter to position B	1.50
Load rolls into receiver 131	0.25
Deposit rolls from 130 onto conveyor C1 Deposit rolls from 131 onto conveyor C2	0.25
Cycle diverter to position A	1.50
Repeat steps	

Table 2

Conveyors C1 and C3 Operating	
TASK	TIME (s)
Diverter in position A	
Load rolls into receiver 130	0.25
Cycle diverter to position B	1.50
Load rolls into receiver 131	0.25
Deposit rolls from 130 onto conveyor C1	0.25
Cycle diverter to position A	1.50
Load rolls into receiver 130	0.25
Deposit rolls from 131 onto conveyor C3	0.25
Cycle diverter to position B	1.50
Load rolls into receiver 131	0.25
Deposit rolls from 130 onto conveyor C1	0.25
Repeat steps	

Table 3

Conveyors C2 and C3 Operating	
TASK	TIME (s)
Diverter in position B	
Load rolls into receiver 131	0.25
Cycle diverter to position A	1.50
Load rolls into receiver 130	0.25
Deposit rolls from 130 onto conveyor C2 Deposit rolls from 131 onto conveyor C3	0.25
Cycle diverter to position B	1.50
Load rolls into receiver 131	0.25
Cycle diverter to position A	1.50
Deposit rolls from 130 onto conveyor C2 Deposit rolls from 131 onto conveyor C3	0.25
Repeat steps	

Table 4

Conveyors C1, C2 and C3 Operating	
TASK	TIME (s)
Diverter in position A	
Load rolls into receiver 130	0.25
Cycle diverter to position B	1.50
Load rolls into receiver 131	0.25
Deposit rolls from 130 onto conveyor C1 Deposit rolls from 131 onto conveyor C2	0.25
Load rolls into receiver 131	0.25
Cycle diverter to position A	1.50
Load rolls into receiver 130	0.25
Deposit rolls from 131 onto conveyor C3	0.25
Repeat steps	

The motion of the infeed conveyor and the distribution sprocket may be coordinated by methods known to those skilled in the art. For example, a programmable logic control (PLC) system such as manufactured by ALLEN BRADLEY can be used to coordinate any combination of the infeed conveyor, the distribution sprocket, the saw blades, the diverter, the index conveyors, and the metering gates. It is desirable that the total speed of the apparatus is sufficiently fast to provide for efficient mass production of the final product. The rate of distribution is preferably at least 300 rolls per minute, more preferably at least 700 rolls per minute. Higher or lower speeds may be optimal for different substrates.

The saw 8 may be configured such that maintenance can be performed during operation or during a pause in operation. For example, the blades can be replaced or inspected when the saw is in the raised position 39 (Figure 1). There can optionally be a shield 81 for the saw 8 (Figure 6). This shield is rigidly mounted to the infeed conveyor and is moved away from the saw when the conveyor is transitioned into its raised position. In the embodiments shown in Figures 1 and 5, there is a honing position 40 located 180-degrees from the cutting area, or down position. In Figure 6, the honing position 41 is slightly above the vertical axis. When necessary, the saw can be rotated to the honing position to improve the cutting performance of the saw. The saw blades preferably have razor edges, that is there are not discrete teeth on the perimeter of the blades.

As illustrated in Figures 26-30, the honing assembly 100 can be mounted on a frame 102. The honing assembly comprises a honing unit 105 for each blade, each unit containing two honing wheels 104. An example of honing wheels which are useful for this apparatus are the RD82-HP-6608 from DESSAU INTERNATIONAL. In the embodiment shown in Figure 26, there is one honing unit for each blade, and each honing wheel 104 is configured to contact the blade at a specific angle relative to the plane of the blade. For example, the honing wheels may contact the blade at an angle of 7-degrees. This results in an angle between the two wheels, and thus an angle at the blade edge, of 14-degrees. The clearance between the perimeter

of a honing wheel and the blade is preferably 0.0625 inch (1.59 mm) so as to provide contact at only one point. In the embodiment shown in Figure 26, the honing units are staggered. That is, the upper units 106 are offset relative to the lower units 108. This is preferred for this embodiment since the width of a honing unit is greater than the spacing between the blades 46. The upper and lower units are mounted on separate horizontal bars 110 and 111 by a clamp 112. Each pair of honing wheels is movably attached to the clamp by a linear slide 114. The position of each honing unit can thus be adjusted to the position and diameter of the blade with which it interacts. The force between the blade and the honing wheels can be controlled through a precision adjustment made with a micrometer thimble mechanism 116. The position of the honing wheels and their interaction force with a blade can be adjusted throughout the life of the blade.

The hones may be rotated by a motor, and the pair of hones for each blade can operate independently or can be operated collectively. Preferably the hones rotate freely, and the blades are rotated when in contact with the hones. For example, the blades can be pivoted close to the honing position and then pivoted in and out of the honing position to make contact with the honing units. A single honing procedure preferably includes multiple contacts between the blade and the hones to avoid overheating the blades. The blades may be operated at a speed similar to the cutting speed, or they may operate at a higher or lower speed.

The method of transporting, cutting, and handling substrates provided for by the described apparatus enables the cutting of low rigidity substrate logs, such as moistened logs, into individual rolls. Distortion of the finished product, especially in terms of shape and cut squareness, is minimized. When processing moistened product, this apparatus provides a sanitary processing environment due to its reduced potential for microbial growth. All components of this apparatus are preferably constructed from materials which are resistant to corrosion.